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THEORETICAL AND EXPERIMENTAL SUPERSONIC LATERAL-DIRECTIONAL STABILITY CHARACTERISTICS

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ABSTRACT

A program has been initiated at NASA Langley Research Center to assess several methods for estimation of lateral-directional stability. As a basis for comparison, experimental data are presented for a simple wing-body vertical tail configuration. The methods for estimating the characteristics include a second-order shock expansion and panel method (MISLIFT), a slender body and "first-order" panel method (APAS), and a "higher-order" panel method for linearized supersonic flow (PAN AIR). The results show that PAN AIR provides accurate estimates of these characteristics at moderate angles of attack for complete configurations with either single or twin vertical tails. APAS will provide estimates for complete configurations at zero angle of attack. However, MISLIFT will only provide estimates for the simplest body-vertical tail configurations at zero angle of attack.

INTRODUCTION

Recent developments in analytical methods have resulted in computer codes for rapid accurate estimates of the aerodynamic characteristics of aircraft and missile configurations at supersonic speeds. Much attention has been given to the development and assessment of these methods for predicting the lift, drag, and pitching moment of complex configurations. Many of these methods have the capability of predicting the lateral-directional characteristics of aircraft and missiles, but their utility has not been evaluated by comparison with experiment.

A program has been initiated at NASA Langley Research Center to provide experimental data on simple wing-body-vertical tail configurations for the purpose of assessing lateral-directional stability estimates at supersonic speeds. This paper will present these data along with an assessment of several of the existing methods capable of estimating lateral-directional parameters. The methods include a second-order shock expansion and panel method[1], a slender body and "first order" panel method[2], and a "higher-order" panel method for linearized supersonic flow[3].

SYMBOLS

The lateral-directional characteristics are referred to the body axis system. The moment reference center was located at 75.6 percent of the body length.

A maximum cross-sectional area of body

C_{l_β} effective dihedral parameter (roll stability), $\left(\frac{\Delta C_l}{\Delta \beta}\right)_{\beta = 0°, 3°}$, where

$$C_l = \frac{\text{rolling moment}}{qAd}$$

C_{n_β} directional-stability parameter, $\left(\frac{\Delta C_n}{\Delta \beta}\right)_{\beta = 0°, 3°}$, where

$$C_n = \frac{\text{yawing moment}}{qAd}$$

C_{Y_β} side-force parameter, $\left(\frac{\Delta C_Y}{\Delta \beta}\right)_{\beta = 0°, 3°}$, where $C_Y = \frac{\text{side force}}{qA}$

d maximum body diameter

l body length

M free-stream Mach number

q free-stream dynamic pressure

α angle of attack

β angle of sideslip

DISCUSSION

The configuration variables are shown in figure 1. The body had a fineness ratio of 11.67 consisting of a 3.5 caliber tangent ogive nose followed by a cylindrical section. The wings were 68° swept delta planforms with sharp leading and trailing edges. Vertical tail planforms are shown for both the single and twin configurations. The vertical tail series for the single vertical tail configuration incorporates leading- and trailing-edge sweep variations as well as taper ratio. The area of these vertical tails is constant and equal to 18 percent of the wing area. For the twin vertical configuration, two areas were used; one is identical to the single tail and the other is one-half that of the single tail. The twin verticals were investigated at lateral spacings of both 2 and 4 body diameters apart. Experimental investigations were conducted in the Langley Unitary Plan Wind Tunnel at Mach numbers from 1.60 to 2.86 for a Reynolds number of 8.2 x 10^6 per meter. The nominal angle-of-attack range was from -4° to 12°.

The features of computational methods used to predict the lateral-directional characteristics are discussed in figure 2. MISLIFT[1], developed at NASA Langley Research Center, is a second-order shock expansion and panel method. The contribution of the body is obtained from a second-order shock expansion theory, and the contribution of the vertical is obtained from a simple panel method. APAS[2], developed by Rockwell, is a slender body and first-order panel method. The body contribution is obtained from a slender body theory which concentrates the surface effects along the centerline of the body. The wing and vertical contributions are obtained from a first-order panel method. Skill is required in modeling the geometry even for the simple first-order methods. For example, it is important to align the edge of the wing panel with the vertical, otherwise erroneous estimates may be obtained. PAN AIR[3], developed by Boeing for NASA Ames Research Center, is a higher-order panel method for linearized supersonic flow. As indicated in figure 2, the entire surface of the configuration is represented by panels. Proper use of PAN AIR requires careful attention to the way in which these panels are defined, especially in the area where configuration components join, such as wing-body or body-vertical junctions.

Figures 3 through 5 present comparisons of the experimental and predicted lateral-directional characteristics at $\alpha = 0°$ for various configurations. The comparisons shown in figure 3 are for four body-vertical configurations. The agreement indicates that all three methods are able to predict the roll stability (C_{l_β}) and the side force parameter (C_{Y_β}) quite well; however, only MISLIFT and PAN AIR predict the directional stability (C_{n_β}) with any degree of success. In figure 4, comparisons are presented for body-wing and body-wing-vertical configurations. The code MISLIFT has not been compared because it can only estimate characteristics for surfaces in their planform plane. APAS and PAN AIR are capable of predicting the lateral-directional characteristics of a wing-body-vertical configuration at zero angle of attack. The agreement ranges from good to excellent for the PAN AIR code. Figure 5 presents a comparison of the theoretical methods with experiment for twin vertical tail configurations at zero angle of attack. The PAN AIR code prediction is in better agreement with experiment than the APAS code, especially for estimation of the directional stability of the configuration with small tails inboard.

Because of the limitations of the methods considered, only PAN AIR will provide estimates of the lateral-directional stability derivatives at angles of attack. Figures 6 and 7 present comparisons of the PAN AIR code predictions with experimental lateral-directional characteristics at angles of attack for Mach numbers 1.60 and 2.86. The agreement for the single and twin vertical tail configurations shown in figures 6 and 7 is excellent for moderate angles of attack. At higher angles of attack and Mach number, the body nose slopes violate linear theory assumption and the solution is invalid.

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CONCLUDING REMARKS

A program has been initiated at NASA Langley Research Center to assess several methods for estimation of lateral-directional stability at supersonic speeds. The methods for estimating the characteristics include a second-order shock expansion and panel method (MISLIFT); a slender body and "first-order" panel method (APAS); and a "higher-order" panel method for linearized supersonic flow (PAN AIR). The results lead to the following concluding remarks:

(1) PAN AIR provides accurate predictions at moderate angles of attack for complete configurations with either single or twin vertical tails.

(2) APAS will provide fairly accurate predictions at zero angle of attack for complete configurations with either single or twin vertical tails.

(3) MISLIFT will only provide estimates for the simplest body-vertical tail configurations at zero angle of attack.

REFERENCES

1. Jackson, Charlie M. Jr.; and Sawyer, Wallace C.: A Method for Calculating the Aerodynamic Loading of Wing-Body Combinations at Small Angles of Attack in Supersonic Flow. NASA TN D-6441, 1971.

2. Bonner, E.; Clever, W.; and Dunn, K.: Aerodynmamic Preliminary Analysis System. Part I.- Theory. NASA CR-145284, 1978.

3. Ehlers, F. E.; Epton, M. A.; Johnson, F. T.; Magnus, A. E.; and Rubbert, P. E.: An Improved Higher-Order Panel Method for Linearized Supersonic Flow. AIAA Paper No. 78-0015, 1978.

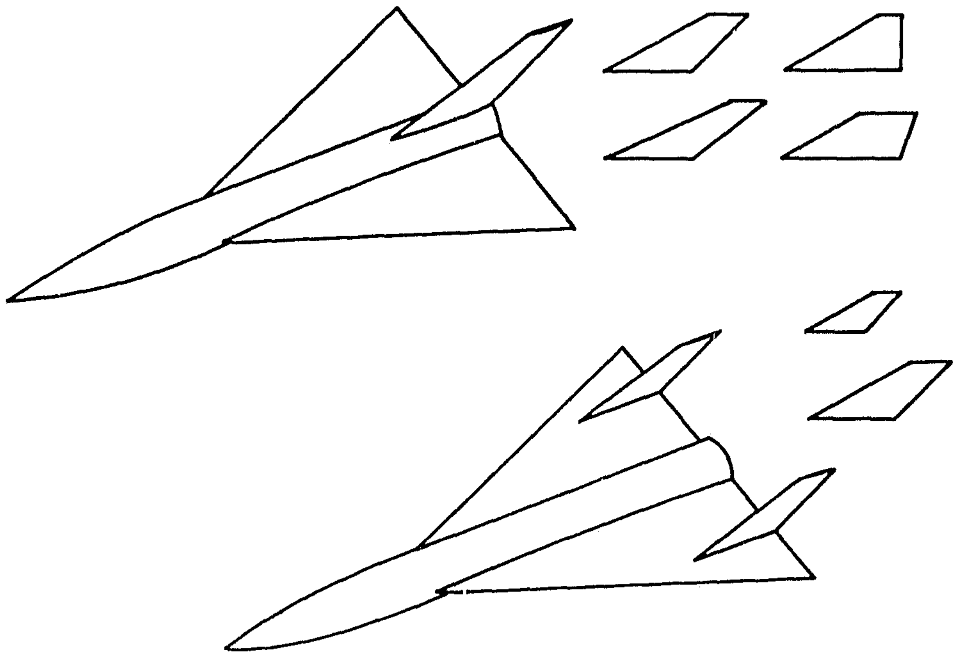

Figure 1. - Configuration variables.

- MISLIFT - A SECOND-ORDER SHOCK EXPANSION AND PANEL METHOD
- APAS - A SLENDER BODY AND "FIRST ORDER" PANEL METHOD
- PAN AIR - A "HIGHER ORDER" PANEL METHOD FOR LINEARIZED SUPERSONIC FLOW

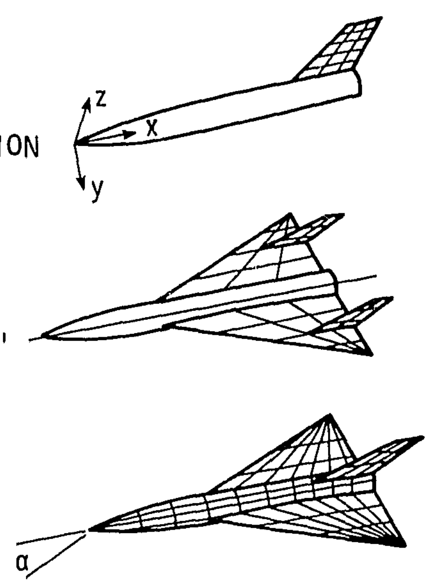

Figure 2. - Computational methods.

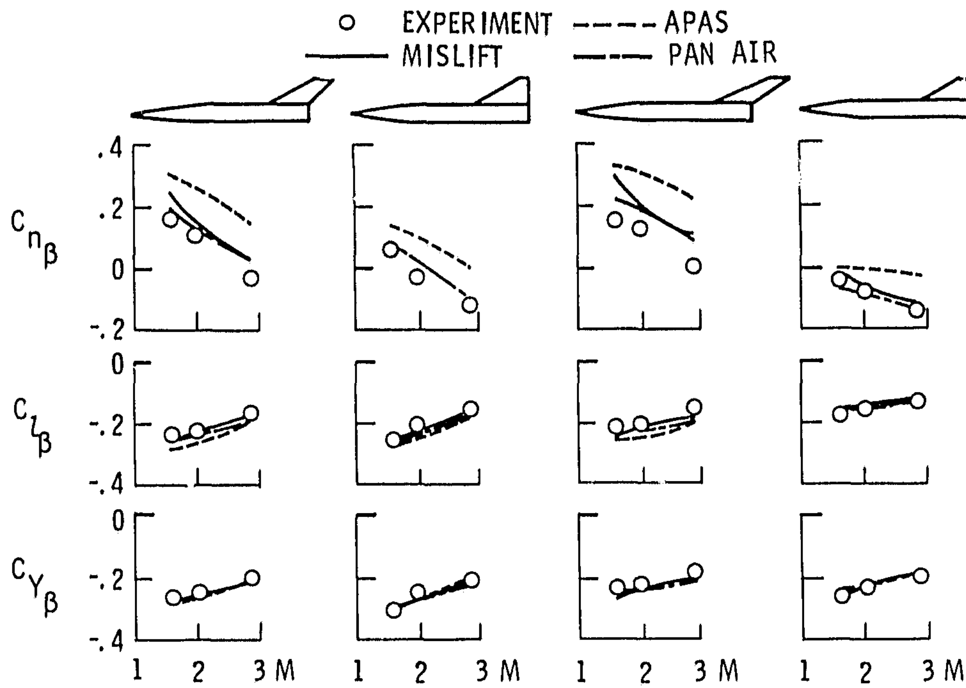

Figure 3. - Comparison of experimental and predicted lateral-directional characteristics. $\alpha = 0^o$; body-vertical.

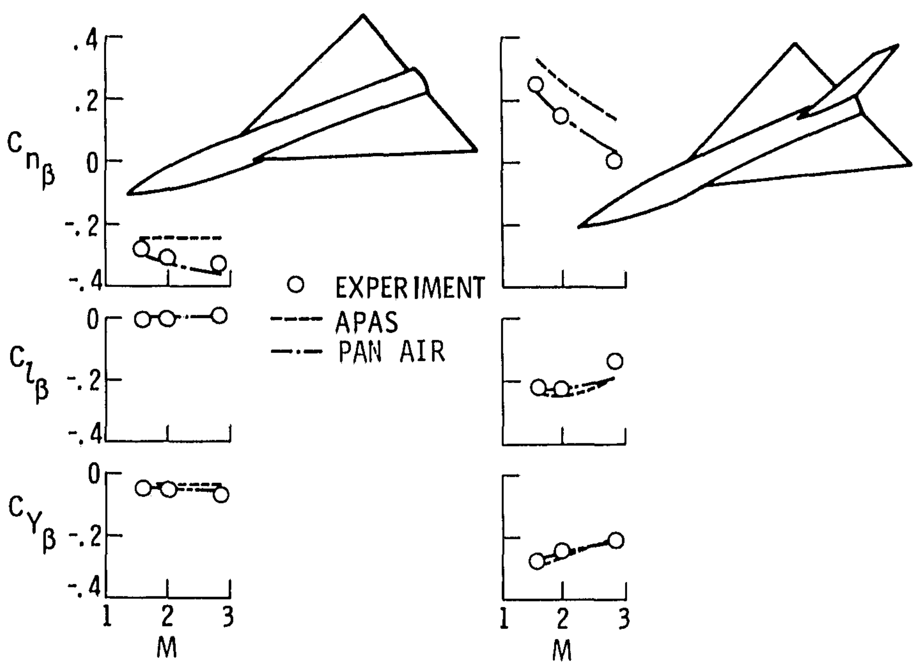

Figure 4. - Comparison of experimental and predicted lateral-directional characteristics. $\alpha = 0^o$; body-wing, body-wing-vertical.

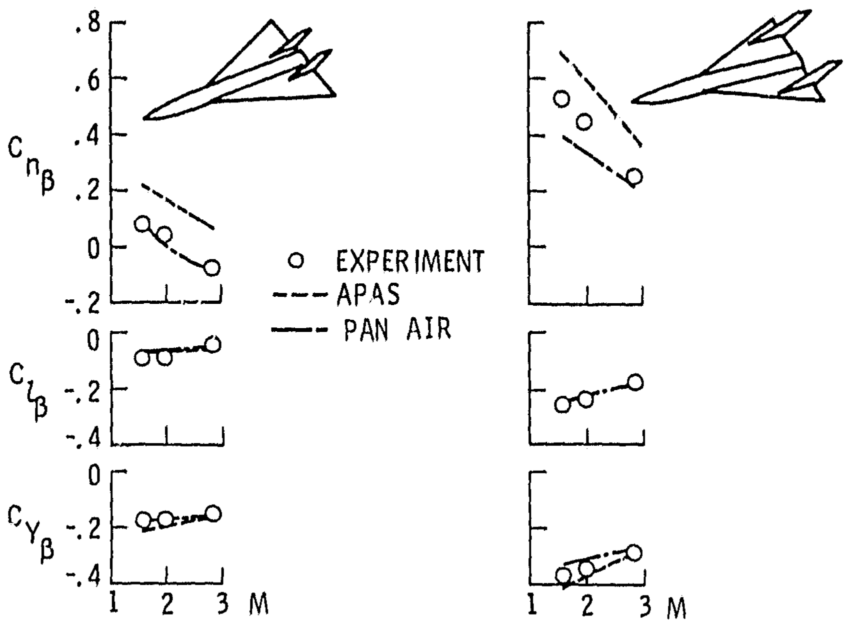

Figure 5. - Comparison of experimental and predicted lateral-directional characteristics. $\alpha = 0^{\circ}$; body-wing-twin verticals.

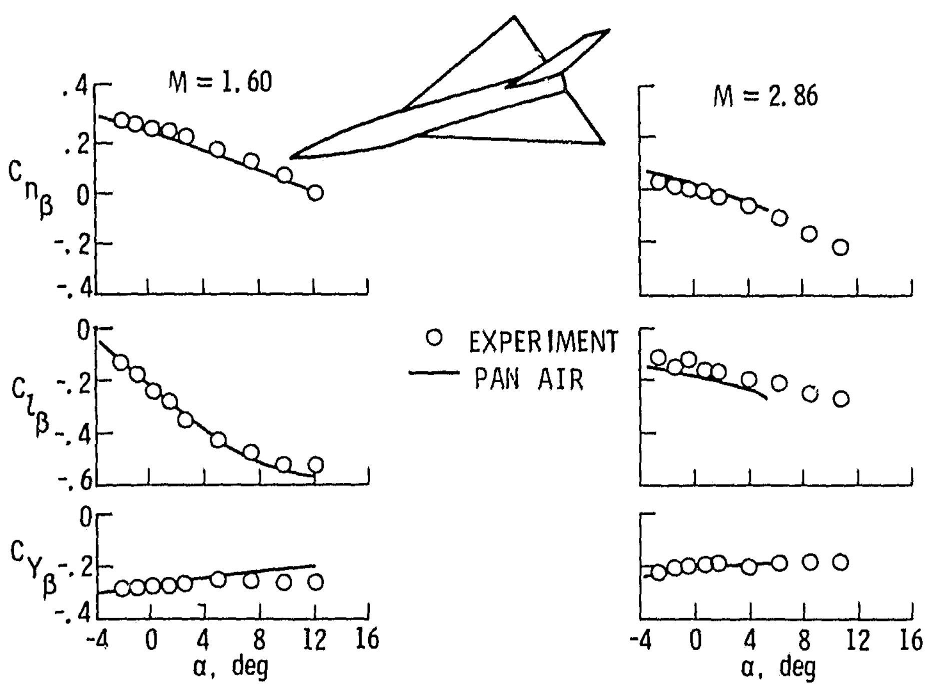

Figure 6. - Comparison of experimental and predicted lateral-directional characteristics. $\alpha \neq 0^{\circ}$; body-wing-vertical.

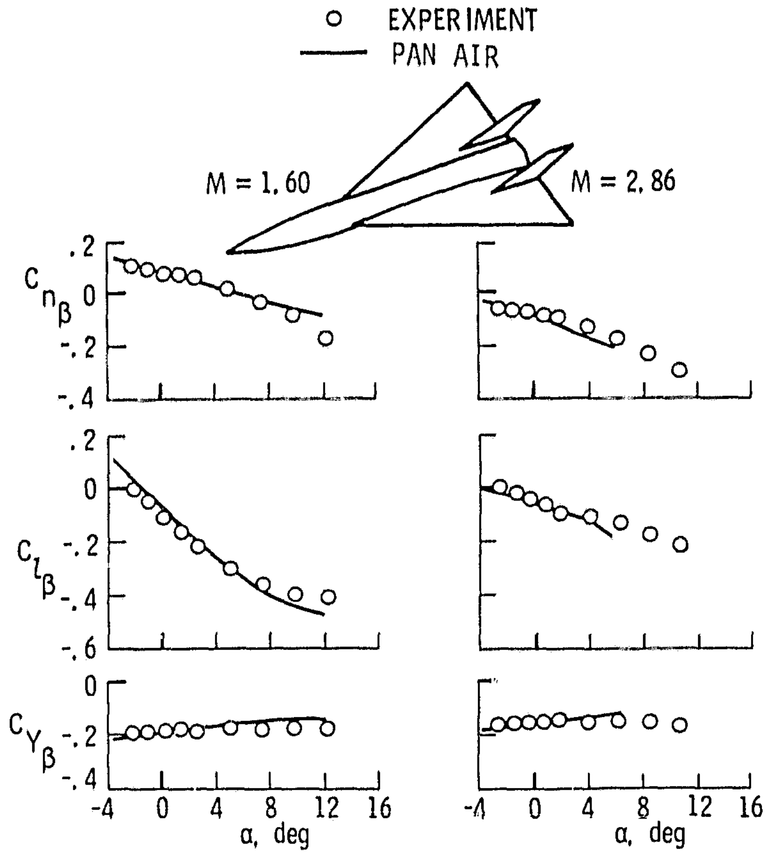

Figure 7. - Comparison of experimental and predicted lateral-directional characteristics. $\alpha \neq 0^o$; body-wing-twin verticals.